Projected Emission Trends and Ozone Trends in the Philadelphia Nonattainment Area" 9/30/93 PENJERDEL Council. More refined analyses need to be performed to assess additional parameters, e.g., humidity levels, cloud cover, etc.; and to correlate to smaller time "bins" (hourly not daily). **Objective** is to **isolate the important parameters and determine when in time they are important** - this should allow a prediction of at risk causes so something may be done about them in advance, but only when necessary; this **"only when necessary" could make operationally expensive solutions viable.** E.g., SCR (I have some limited cost information from a text and a report) my material indicates the costs can vary significantly with location but leads me to accept as reasonable representative numbers 5-10 mils per kwhr for continuous operation and will exceed 5-10 mils per kwhr for intermittent operation but for 5-10 % of the time (at risk times only) operation may be more like 1-3 mil per kwhr (a factor of 3-5 less) when spread over the total kwhrs. Thus at my homes 30 kwhrs/day usage level continuous SCR operation could cost me $4.50/month, while intermittent operation might cost a dollar/month. I might object to $4.50 a month, but probably not to a dollar, especially if it brings substantially cleaner air and **for sure if it relieves us of a larger expense in some other marginal pollution reduction area programs.**

2. Look at the least cost ways to get **long term and near term major NOx reductions**, but **<u>only when at risk</u>**. SCRs look good at 1-2 mils/kwhr ave, but other elec generation items to study for **reducing NOx on "at risk" days** are: **use of low nitrogen coal, lean natural gas or lean hydrogen combustion**, mixture of gas/liquid and solid fuel and **alternate processes**, e.g., lean natural gas or gasoline SI IC prime movers, nuclear, **hydro (use limited capacity for at risk times only, e.g., purchase Canadian Hydro, but only when needed to meet ozone standards)**, **importing electricity from remote locations to "at risk" locations**, increased EGR, increased water injection, pre-cooling mixture, increased **(lean burn)** air flow and/or pressure and/or finer coal particles, hydro and other storage media). Some of these **items may raise cost/kwhr and/or may have insufficient supply to continuously provide the necessary kwhrs, but if only needed a fraction of the time, the <u>expense may be quite acceptable and the supply quite adequate</u>**, i.e., only what is required and only when!

3. Lobby the Govt to **establish firm standards for truck engines: <0.40 lb fuel/hphr, <u>≤0.25g/hphr of NOx</u>**, <0.5 g/hphr of CO, <0.25 g/hphr of HC, <0.05g/hphr of particles and at **<u>no increase in cost (inflation adjusted) of ownership</u>**!. **In the interim establish Truck (new standard's trucks exempted) restrictions** during at risk contribution times and locations; e.g., time critical produce trucks may need to move, but parcel post trucks may not be time critical and delayed delivery might be worth the NOx elimination at that time and place (e.g., movement and/or deliveries after 3PM of mail and packages). SEPTA might consider curtailing some service between 9AM and 3PM to **get some "filthy" diesels off the road** on at risk days. Lawn mowers (voluntary) only after 4PM on at risk times and locations, etc, etc. **Inconveniencing people (especially if they are the main contributors) <u>a few days a year for major gains may be quite acceptable</u>, but a lot of people being inconvenienced every day, especially when not necessary and/or their impact on ozone level is minor, is not!**

4. The automobile and light trucks have made good progress and as Tier I vehicles continue to replace older vehicles their contribution to the problem should continue to diminish. Still room for improvement and the Govt needs to establish **standards for auto at about 45mpg, <u>≤0.1g/mi NOx</u>**, <0.25 g/mi CO, <0.10 g/mi HC <0.01 g/mi particles and at **<u>no increase in cost (inflation adjusted) of ownership</u>**; and this should be done, but it is not as time critical as dealing with power plants and heavy trucks.

Notes: a. ***<u>I predict that these performance standards (autos&trucks) as achievable</u>*** with always homogeneous &lean (low to mid 20s A/F unleaded SI gasoline engines at proper compression ratio for A/F ratio being used, higher peak pressures and increased expansion ratios, substantial friction reduction designs, significant weight reduction designs, greatly reduced crevice effect designs and fast opening valve designs. See tables (p. 4) for my model's predictions.

b. Some **restriction possibilities: voluntary**, e.g., curtail driving between 9AM and 3PM on announced alert days; and/or **mandated**, e.g., color coded vehicle safety stickers based on vehicle EPA test pollution values (allow voluntary testing for reclassification) for model with use considerations factored in; color based on contributor's significance and time criticality of the trip - green drive any time , yellow during non alert and not severe ozone alert; and red may drive only during non alert times on high polluting vehicles for at risk times and locations; no off-road construction before 3PM at alert contributing locations on alert days, etc., etc..

5. **Encourage our upwind states to also follow PA's lead**, for the cleaner air we receive from them the better our air will be!

6. **<u>Input these assumptions (individually and together) into the ozone transport model</u>**: 80-90% reduction in NOx from stationary plants, 0.25g/hphr for all highway and off road IC engines (and turbines), and assume upwind states follow PA's lead. i.e., reduce incoming air pollution content accordingly! And from this scenario determine ozone "hits" and severities; and determine the residual major contributors to ozone level and the contribution of each! And compare effectiveness (ozone "hits" and severities) against existing and currently being considered options.

6a. If ozone transport model is expensive to "run"; **consider alternative "filtering" less expensive approaches** and use the ozone model for confirmation of approaches that pass the "filter".

7. Where existing law and/or guidance imped progress toward the most effective and most cost effective actions - **<u>get the laws and/or guidance corrected</u>**!

Remember **<u>focus on only doing what is necessary and only when necessary</u>**. This approach could allow operationally high cost very effective pollution reducing measures to become fiscally viable. I realize this approach may differ from guidance, but not the law; e.g., 104stst.2412 middle of page " Reasonable further progress - .. means such annual incremental reductions... as are required ... for the purpose of insuring attainment ...

standard by ...." - just says what is required to meet standard .120ppm ozone; silent on how applied, i.e., only reducing when needed appears within the law. Another section, bottom of page 104stat.2409 "... plan's purpose ... reducing severity and number of violations ... standards ....expeditious..."; intent pretty clear to me minimize the days .120ppm ozone is exceeded and when exceeded limit the severity and expeditiously! **Only during at risk times and locations appears within the law as written**; and if not the law needs to be changed!

Using yearly pollution amount as the figure-of-merit **allows at risk times to be unchanged and/or even increase** as long as pollution amounts are offset during other non at risk times - therefore not necessarily effective and allows for increased severity and occurrences actions! By thinking in terms of reducing average daily amounts that suggest continuous use it **"prices" operationally expensive** (but limited application not expensive) **very effective pollution reducing methods <u>out of reach</u> for at risk days <u>when needed</u>!**

My performance predictions for IC engines (for engines designed along the lines described in note a page 3) follow (along with some EPA information for comparison);

<u>Automobile predictions</u> (Taurus size vehicle):

		Pollution g/mi Taurus vehicle					Source
Configuration	MPG	NOx	CO	HC	CO2	Particles	
'89 Taurus/Cougar	19.6	0.55	1.92	0.39	355	-	EPA
Standards (after '93)	-	.4/.6	3.4/4.2	.25/.31	-	-	104STAT.2474
Standards(Phase II)	-	0.2	1.7	0.125	-	-	104STAT.2476
Predictions:							
Stoich(Taurus/Cougar)	19.6	0.52	3.63	0.23	385	0.009	My Model
Interim	28.0	0.10	0.20	0.03	282	0.007	"
MPEC	37.9	0.07	0.15	0.02	222	0.005	"
Advanced MPEC	48.5	0.11	0.12	0.01	172	0.004	"

My recommended FTP 2002 standards (new fleet average - conversion factor between Taurus and smaller average fleet vehicle is 0.74):

	>45	**<u><0.10</u>**	**<0.25**	**<0.10**	**<220**	**<0.010**

<u>Heavy Duty Truck engine predictions:</u>

	lb/hphr	Pollution g/hphr					Source
Configuration	SFC	NOx	CO	HC	CO2	Particles	
Diesel(1988 Cert.)	0.46[a]	10.7	15.5	7.5	-	0.6	EPA420F94001
(1998 Cert.)	0.46[a]	4	15.5	1.3	-	0.1	"
(94 model test)	-	4.58	1.45	0.28	-	0.11	EPA11/2/94memo(Ann Arbor;A. Stout)
Predictions:							
Stoich	0.685	1.14	7.9	0.50	834	0.020	My Model
Interim	0.471	0.21	0.42	0.06	598	0.014	"
MPEC	0.361	0.15	0.33	0.04	490	0.011	"

Advanced MPEC	0.277	0.24	0.25	0.01	372	0.009	"

Note a: values from EPA material but not EPA420F9401

My recommended 2002 certification requirements (new truck fleet average):
<0.40 ≤0.25 <0.50 <0.25 <500 <0.050

Discussion of tables:

The important point for ozone is homogeneous lean 21-25 A/F engines are predicted at very low NOx (0.1 g/mi vs 2 for 1990 actuals - 95% reduction predicted); also predicted as more efficient (when designed as stated); and lower in CO, HC, CO2 and particles. Low NOx and CO is consistent with all texts and test material I have on the subject of homogeneous lean (20s A/F) SI IC engines (specific references will be provided when I know what would be useful)!

Diesels (I believe because they are stratified, i.e., high polluting rich pockets) are high in NOx and particles! This causes HD trucks to be a major contributor to highway NOx. My information un-weighted and weighted follows: Note: My data base is not as complete or current as I would like but I did, with limited analyses, determine a **weighting factor for highway vs power plant NOx.** The following table (using my factor of 3.5:1) provides my estimated relative importance (i.e., **% of NOx ppm**) for key categories:

	1:1 weighting			3.5(tbr):1 weighting		
	1990	2010		1990	2010	
		Tier 1*	MPECs		Tier 1*	MPECs
Highway						
cars&light trucks	6%	1.5	0.4	14%	3.5	0.9
heavy duty trucks	14	15	15	30	34	35
other	4	4	4	8	9	9
Other						
elec generation	67	69	69	42	47	49
other	9	9	10	6	7	7

Notes:*= meeting Tier 1 requirements

Table message: reduce cars&light trucks where cost effective; but must make substantial reductions in heavy duty trucks and elec generation!

Engine definition summaries:

Taurus engine: six 3.5 in diam by 3.1 in stroke pistons; nominal fpm 1208 ft/min ave piston velocity; stoich A/F and TWC catalyst.

Interim engine: six 3.15 in diam by 3.2625 in stroke pistons; nominal fpm 1500 ft/min ave piston velocity; homogeneous A/F - 21 A/F at max load and 23 at off load and at 12.1 compression ratio; inlet throttling load control; a substantially reduced crevice ring; catalyst and full friction reductions.

<u>MPEC engine</u>: four chambers (one compressor, 2 combustion chambers and 1 aux chamber); homogeneous A/F - 21 at max load and 25 at off load and at 18 compression ratio with 1/3rd of the compressor heat of compression lost between the compressor and the combustion chamber inlet; a substantially reduced crevice combustion chamber ring; top center combustion chamber volume control; fast opening valving in and out of the combustion chambers; stroke control of both the compressor and aux strokes for load control; and full friction reductions. 6 inch diameter charging piston, 2.3 inch stroke at max load, 1.98 inches at 68%load and 0.828 inches at 30%load; 2.3inch diameter combustion piston (two), 2.3 inch stroke with 3.37 cuin TDC volume at max load, 2.90 at 68% load and 1.25 at 30% load; 4.5 inch diameter aux piston at 4.6 inch stroke at max load, 2.875 at 68% and 1.725 at 30%. 0.04 inch TDC clearance for charging and auxiliary pistons. 21 A/F at max load and 25 at off load. 10% burn complete at TDC.
<u>Advanced MPEC</u>: an MPEC with an extra cam driven charging piston for each combustion chamber with inlet valving from the charging pistons to the combustion chambers in the center of the combustion chamber and charging the combustion chamber during the compression stroke of the combustion piston.

Additionally, there are a number of design options available to further reduce MPEC (and sometimes others) NOx; e.g., delay ignition, lower mixture temperatures (allow more charge heat loss between the compressor and the combustion chamber inlet), slower combustion rate and I also have a mechanical modification that consistently reduces NOx in about half (however I do not wish to complicate the design with this mechanical mod if not required).

Recap:
1. Identify significant contributors to the actual time and place of ozone exceedence and when of significance.

2. Devise plans for large <u>(80-90%) NOx reductions</u> of these identified sources at the times they are contributing to an exceedence. Note: not going to get there if main culprits are not effectively dealt with at the necessary times; and using limited resources to pursue minimal and/or negligible ozone reducing actions only takes resources away from effective actions!

3. "Best interests of our society" should be the criteria for selecting actions; and cost is a major figure-of-merit; therefore reduce all actions and groups thereof as to effectiveness at reducing ozone "hits" and severities and society's cost and intrusion!

4. NOx controls and cost are areas to concentrate on. Ultimately I view ozone as a cost problem, i.e., I believe ultra low NOx (0.01-0.02ppm) levels are attainable, only question is cost; therefore, what is the lowest cost approach that fairly spreads the burden!

Anybody have any questions, additional technical information or information references, please contact me.